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NASA TECH BRIEF

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Low-Noise K_u-Band Receiver Input System

The problem:

Receivers capable of K_u-band operation include a traveling-wave maser operating at frequencies between 14.3 and 16.3 GHz. The required operating field for this maser must be continuously adjustable from 7,000 to 8,000 gauss. Prior masers included permanent magnets capable of 2,500 gauss for the S-band and 500 gauss for the X-band. These magnets weigh 180 kg or more. The size of the magnet was another limiting factor and prevented the designer from increasing the magnetic field while maintaining the spatial magnetic uniformity and large gap necessary to enclose the closed-cycle refrigerator (CCR) shields. A third limitation, sensitivity of the permanent magnet to the Earth's magnetic field, resulted in phase variations of the received signal through the maser as the antenna is rotated. Also, instability caused by relative motion between the maser and the permanent magnet was difficult to eliminate.

The solution:

An improved maser for the K_u-band and a superconducting magnet, which operates in the vacuum of a closed-cycle helium refrigerator, comprise a low-noise, reliable, field-operational receiver input system. The superconducting magnet weighs 63 kg. A superconductive switch, heated via radiant energy from an incandescent lamp, improves the magnet control-circuit response time.

How it's done:

A Cioffi-type superconducting magnet, designed to attain magnetic fields of up to 10,000 gauss, provides phase stability of the signal with less than 1° variation through the maser. Due to the high relative permeability of the iron in the magnet, the iron acts as a shield against external magnetic fields. The superconducting magnet is mounted in the same 4.5-K heat station on the CCR as the maser and operates in a persistent mode. The temperature inside the CCR is stable to within 0.001 K, eliminating temperature compensation of the magnet. Nine U-shaped shields are each made of a 50-mm wide by 0.27-mm thick tape of copper-plated Nb_3Sn material. The magnet is wound with 0.127-mm-core NbTi wire. The pole pieces and return paths are Hyperco 27 machined and annealed.

With a persistent-current superconducting magnet, it is necessary that the junction where the winding ends are joined has zero resistance below the critical temperature for the current necessary to operate the magnet. The joint is made by stripping the cladding off the wire and winding the exposed superconductor into a filament. This filament is then compressed into a copper matrix with 12 mm of superconducting wire extending through. This type of joint has passed a persistent current of 20 A for 3 weeks, indicating an upper limit on the junction resistance on the order of 10^{-11} ohm.

The superconducting switch and magnet coil are located in the vacuum of the CCR. The switch consists of an NbTi superconducting switch-wire shunt that passes through a radiation shield containing a filamentary light bulb. The lamp provides radiant heat to operate the switch by varying shunt resistance. While the lamp is glowing, current through the magnet can be changed via an external power supply. As long as there is a charging current in the magnet greater than a certain minimum threshold, the light bulb may be turned off, and the induced voltage

(continued overleaf)

(approximately 2 mV minimum) across the magnet will keep the switch wire normal. When the current in the magnet reaches a stabilized level, the switch wire will become superconducting, and the magnet current will operate in a persistent mode, at which time the external power supply can be turned off.

The slow-wave structure of the traveling-wave maser consists of a comb system with ruby on one side. Alumina on the other side also supports the isolator material. Radiation at the pump frequency is coupled to the ruby through shaped alumina strips. The ruby bars are forced against a copper comb by pressure from berryllium-copper springs located between the bars and the center divider of the traveling-wave maser structure. The springs also serve to hold the isolators in place. Contact between the ruby bars and the comb completes a conductance path for heat transfer from the ruby bars, through the copper mass constituting the body of the traveling-wave maser, to a flange which supports the entire maser.

Ruby crystal misorientations on the order of $\pm 1^\circ$ can be tolerated without degradation of performance. As a result, orientation and assembly procedures need not be as closely controlled as with the usual 54.7° ruby orientation. Crystal quality requirements are also readily met by current crystal-growing procedures. Efficient operation of the maser is obtained by pumping with a push-push technique; this provides larger pump-transition probabilities and higher measured-inversion ratios than the prior push-pull method.

Note:

Requests for further information may be directed to:

Technology Utilization Officer
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Patent status:

NASA has decided not to apply for a patent.

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